

# BULLETIN



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# THE BENEFITS OF HYDROLOGICAL FORECASTING

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*This article is a condensed version of a Technical Report, with the same title, in the process of being prepared.*

Water is an essential requirement in sustaining life, and its various uses affect almost every phase of human existence. From a national perspective, water is abundant in the USA but precipitation is not distributed uniformly throughout the country. As a result, floods and droughts are common. The National Weather Service (NWS) maintains a round-the-clock vigil of rivers throughout the country and issues watches and warnings to protect life and property when the threat of flooding does occur. Unfortunately, flood damage continues to accrue, despite structural and non-structural mitigation measures. National annual flood damages are estimated to be US\$ 3.6 billion (USACE, 1986; 1996). In this report, all estimates of flood damages both incurred and prevented are based on the 20-year period from 1977 to 1996 and are indexed to 1996 cost levels.

In the USA, the principal structural solution to flood damage reduction is that of reservoirs and levees, while the primary non-structural means is that of timely and accurate hydrological forecasts. The US Army Corps of Engineers (USACE) and US Bureau of Reclamation (USBR) flood-control projects prevent an annual loss of US\$ 17.8 billion, revealing a potential of US\$ 21.4 billion in flood damages annually. Additionally, non-structural flood-mitigation measures make the average annual flood potential even higher. A hydrological forecast is only of value, however, if it elicits a response from the floodplain user that leads to an effective action. For example, when the flood warning is issued to the general public through appropriate dissemination channels, a benefit can accrue only through evacuation, flood-fighting measures or shutdown of facilities to reduce potential flood losses.

Flash-flood watches and warnings, river and flood forecasts, and water-supply forecasts are the major hydrological services provided by the NWS. Hydrological forecasting benefits from flood mitigation result from three categories: optimizing reservoir operations from federal projects; taking advance measures to fight flooding (temporary levees, sandbags); and increasing lead time (time between the issue of the warning and occurrence of the flood) to take action during short-term flood events. The short-term events include flash floods, which can develop up to six hours from the time of heavy rainfall. As might be expected, the primary objective of flash-flood warnings is to save lives, since there is so little time to save personal belongings and property. For floods with longer lead times, the effectiveness of the warnings is measured in terms of both lives and property saved. Benefits associated with hydrological forecasts are attributed to both structural and non-structural actions. But, in order to compute benefits from hydrological forecasts, damage estimates under natural conditions must be developed.

USACE, while preparing its comprehensive river basin study reports, developed stage-damage curves for each river reach within the river basin under investigation. Once a flood-damage history has been completed within a typical river basin, the process begins of computing benefits from both structural and non-structural solutions to flood damage mitigation. The structural solution considers simply the impact with and without the flood-control structure. USACE and USBR rely heavily upon the NWS's hydrological forecasts to operate their projects. The flood-control projects have been designed to reduce damage downstream by holding floodwaters within the reservoir based on a prescribed operational schedule. Floods are extremely unpredictable, however, and it is not always possible to obtain maximum benefits from mitigation measures. In the majority of floods, NWS forecasts the stage and time that the flood crest will occur at key downstream locations. This makes maximum

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# Flood damage

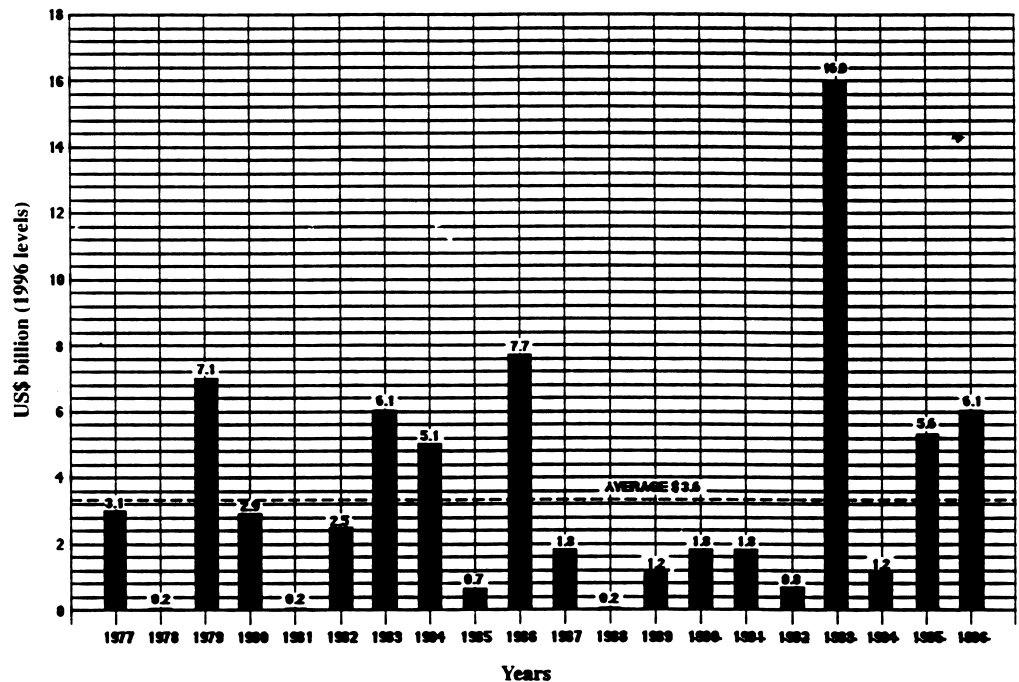


Figure 1 — Flood damage in the USA, 1977–1996

economic benefits from flood-control operation more attainable. Consistent with the operational experiences of both USACE and USBR, senior hydrologists in the NWS and USACE headquarters offices have informally agreed that NWS hydrological forecasts account for approximately 5 per cent of the total flood damage prevented at USACE reservoir projects nationwide. By adopting this conservative 5 per cent adjustment factor, benefits are obtained by using NWS hydrological forecasts to attain the best estimate of maximum net benefits associated with reservoir flood-control projects. These economic benefits are estimated to be US\$ 890 million annually.

In addition to the benefits from federal reservoirs, hydrological forecasts produce economic benefits from non-structural measures. The first involves long-term hydrological forecasts where enough time exists to construct temporary levees or other emergency measures. Long-term hydrological forecasts are generally related to those areas of the USA where snowmelt runoff is a major factor in flooding. In the 20-year period in question, an analysis was made of the economic benefits that resulted from NWS long-term hydrological forecasts using historical data from multiple technical reports. The estimates reflect the difference between damage (natural damage that

would have resulted with and without the temporary levee or sandwall) incurred during the long-term flood event and the cost of the flood fight.

Besides levees, sandbags and evacuation, other actions help mitigate flood damage. One example occurred at St. Paul, Minnesota, during a long-term snowmelt flood event. Sufficient lead time enabled officials to have all planes removed from the downtown airport, which was eventually under floodwater. Also, at a railroad depot at risk from flooding, all movable equipment was relocated and the yard was closed down. In another example of adequate lead time, a sewage-treatment plant on the Mississippi River downstream from St. Paul was fortified against flooding with a second wall of sandbags.

The economic benefits of flood mitigation range from zero to US\$ 1.43 billion annually with an average benefit of US\$ 140 million. It must be noted that long-term flood events do not occur each year because the amount of snow on the ground is sometimes insufficient to produce above-bank streamflow conditions or because hydrometeorological factors allow the snow to melt at a rate slow enough not to produce damaging flood levels.

Short-term hydrological forecasts apply to those floods where increasing the lead time allows

the population to fight the flood, move valuable property or evacuate the area. Several reports have been prepared on the benefits resulting from hydrological forecasts that used a variety of mathematical models in concert with actual field data obtained by interviewing floodplain residents and owners of commercial and industrial property. The interviews were conducted shortly after a notable flood event. An analysis was made to determine whether there had been sufficient lead time to take appropriate remedial action. The models assume that a commercial or residential establishment subjected to a similar depth of flooding in one part of the floodplain will receive identical flood damage. A summary of seven historical reports shows that mitigated flood damage varies from 10 to 43 per cent of actual damage (Day, 1996; Houghton, 1962). A conservative benefit estimate of 10 per cent of the total flood damage suffered is attributed to NWS hydrological forecasts for short-term flood events. Again, the figures shown in the 20-year report period reveal that short-term NWS hydrological forecasts save US\$ 360 million annually.

The percentage of annual hydrological forecasting benefits of flood mitigation in the USA are the following: reservoir optimization, 69 per cent (US\$ 890 million); short-term forecasts, 25 per cent (US\$ 360 million); and long-term forecasts, 6 per cent (US\$ 140 million). Annual benefits associated with hydrological forecasts resulting from flood mitigation alone range from US\$ 0.13 billion to US\$ 3.88 billion with an average annual value of US\$ 1.4 billion.

The principal economic benefits associated with NWS hydrological forecasts are related to flood mitigation. Nevertheless, the NWS provides hydrological forecasts of river levels that are also extremely valuable and produce substantial benefits annually to the USA. Forecasts of both high and low flows also contribute important input to the efficient operation of any water resources system. The NWS is actively pursuing its Advanced Hydrologic Prediction System (AHPS), which will significantly increase not only the flood mitigation benefits but will also greatly assist emergency managers and water-resources decision-makers in projects concerning water supply, navigation, hydroelectric power generation, irrigation and recreation. NWS modernization, technological advances, improved use of quantitative precipitation forecasts and operational experiences will produce a suite of hydrological forecasts from days to months in the future.

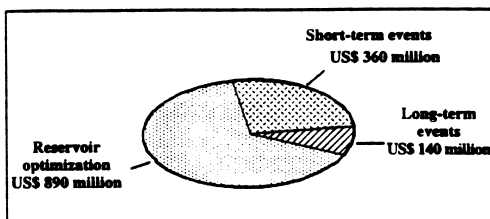


Figure 2 — Annual economic benefits of hydrological forecasting in the USA in millions of dollars (1996 cost levels)

Hydrological forecasting benefits are not limited to the USA. China and Germany both provide excellent examples of recent major success in flood mitigation using hydrological forecasts. In China, on the Changjiang in June/July 1995, benefits from hydrological forecasts alone were estimated at approximately US\$ 1 billion by the Changjiang Water Resources Commission (Wang Jun, 1996). In Germany, damage from the River Rhine flood of 1995 was about half that experienced during the 1993/1994 floods in the same area (Federal Institute of Hydrology, 1994). The large benefits are the result of people in the floodplain reacting to the flood warnings and evacuating promptly.

Although floods and droughts will occur in the future, structural and non-structural measures can do much to mitigate economic impacts and reduce the potential loss of life during these hydrological extremes. In the USA, NWS hydrological forecasts have effectively reduced flood damages by almost US\$ 1.4 billion annually. NWS modernization and AHPS will provide supplementary economic benefits to the nation.

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